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Moger, IV

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(54) **PARTICULATE LADEN FLUID VORTEX EROSION MITIGATION**

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(Continued)

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CPC ***F15D 1/06*** (2013.01); ***F15D 1/02*** (2013.01); ***F15D 1/025*** (2013.01); ***F16L 57/06*** (2013.01)

(58) **Field of Classification Search**
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(Continued)

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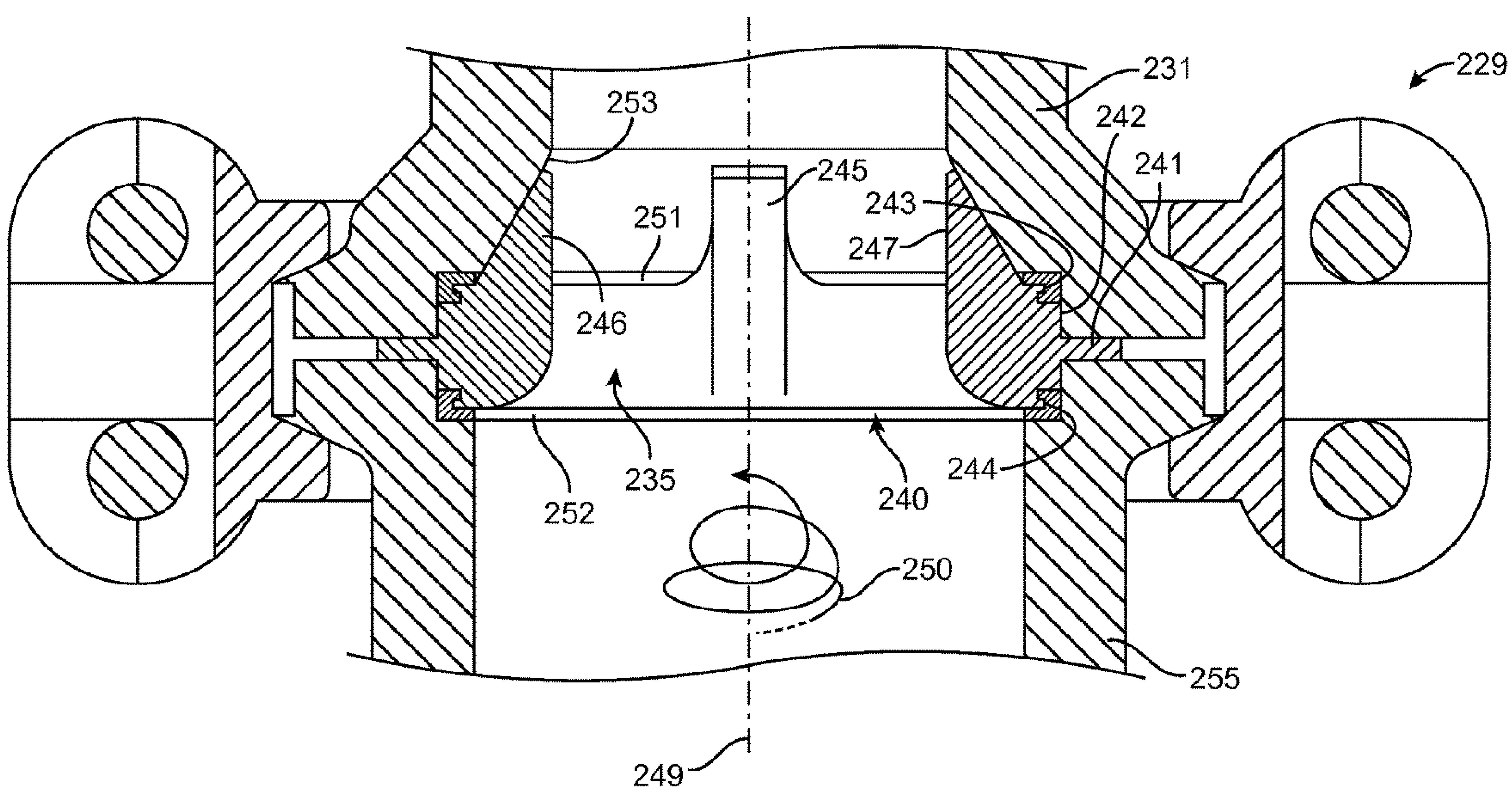
(57) **ABSTRACT**

A vortex suppression element is configured to be inserted in a pipe joint between pipe segments for mitigation of erosion from particulate laden fluid flowing in at least one of the pipe segments. The vortex suppression element includes an outer ring, and an array of inner axial vanes secured to the outer ring. A method of using the vortex suppression element includes locating, in the pipeline, a pipe joint at a location where a vortex would form in the particulate laden fluid flowing in the pipeline in the absence of a vortex suppression element in the pipe joint in the pipeline; and inserting the vortex suppression element in the located pipe joint in the pipeline.

16 Claims, 9 Drawing Sheets



(51) **Int. Cl.**
F15D 1/02 (2006.01)
F15D 1/06 (2006.01)
F16L 57/06 (2006.01)

(58) **Field of Classification Search**
CPC F15D 1/02; F15D 1/025; F15D 1/06; F16L 57/06
See application file for complete search history.

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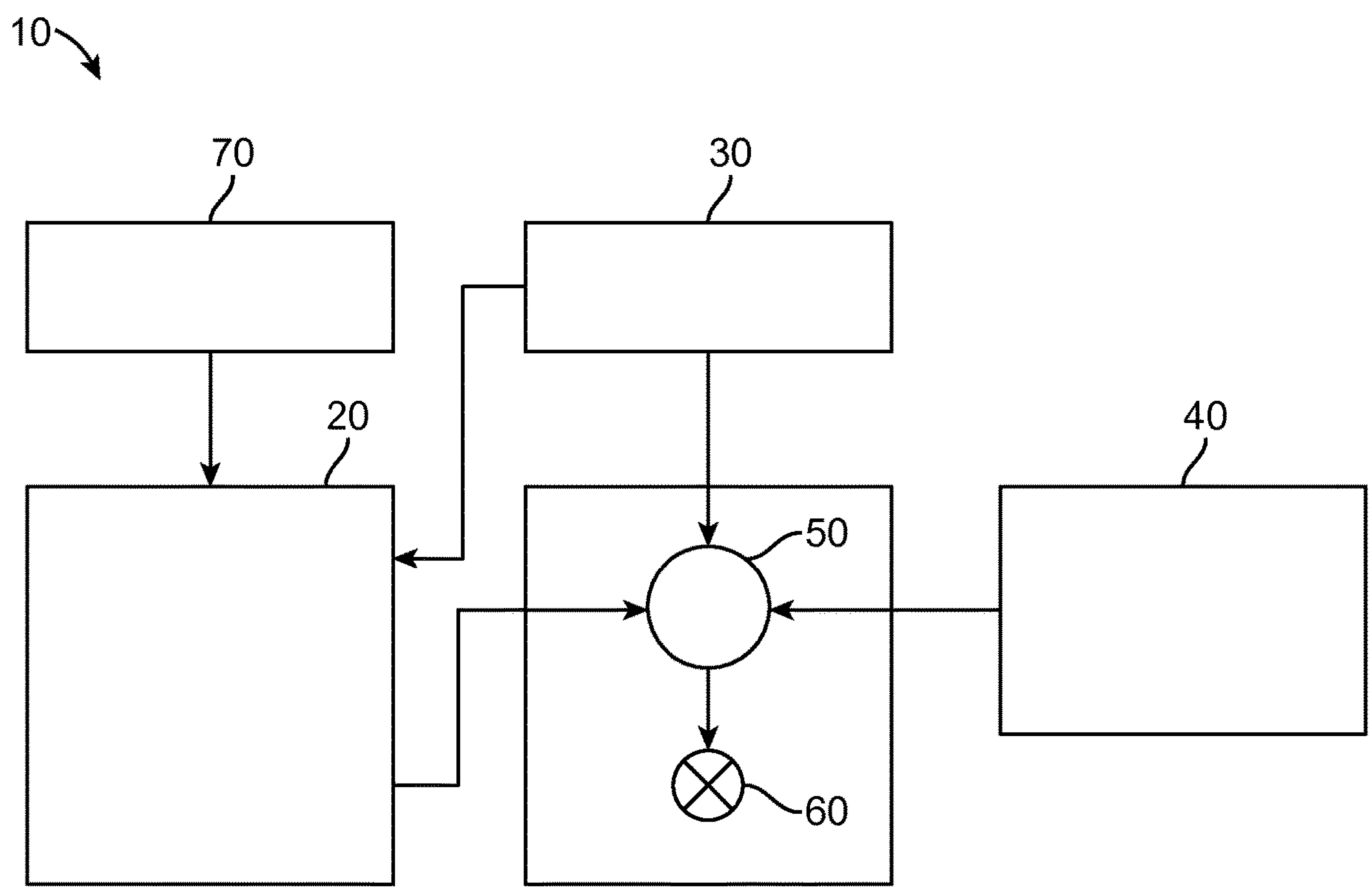


FIG. 1

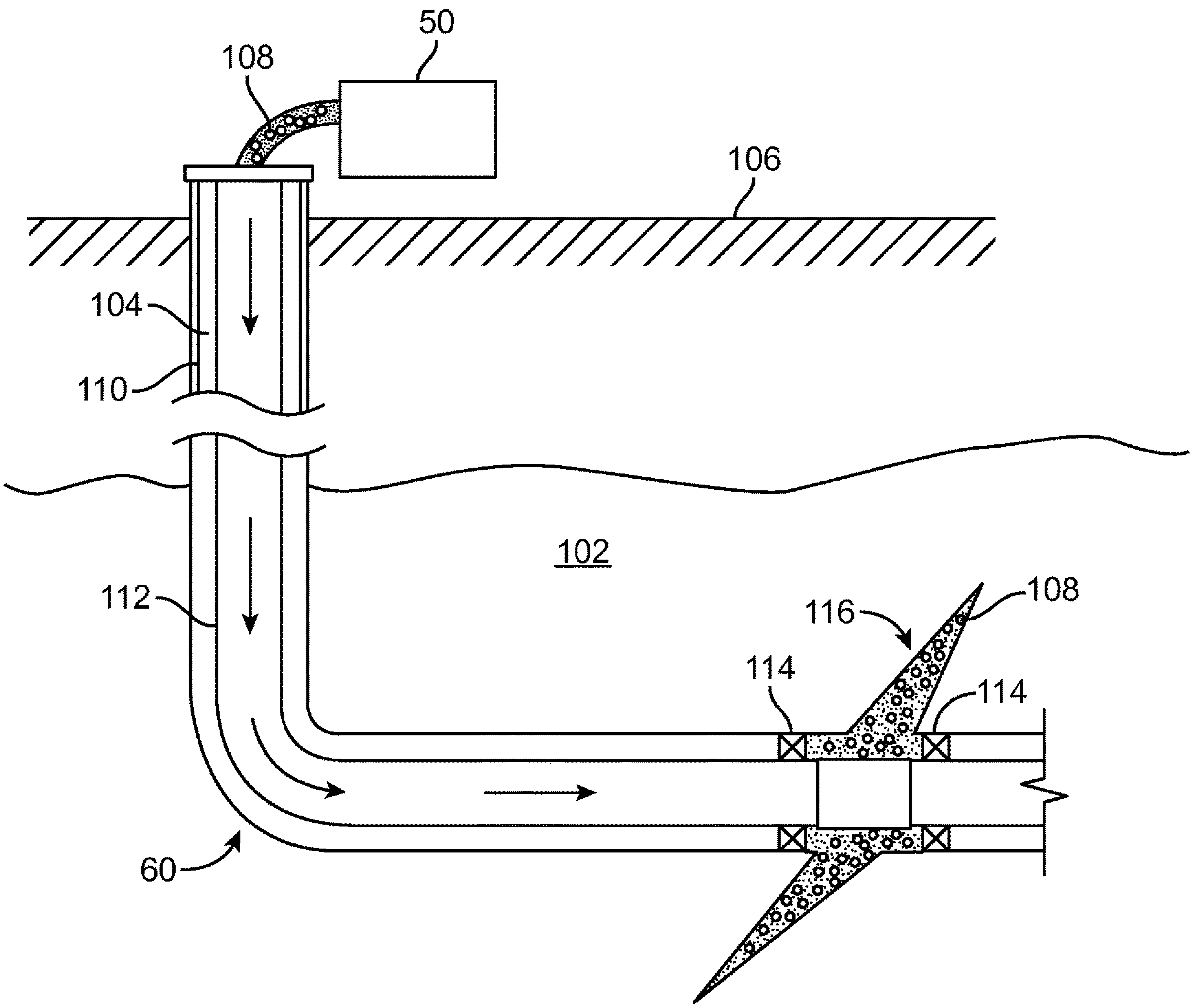
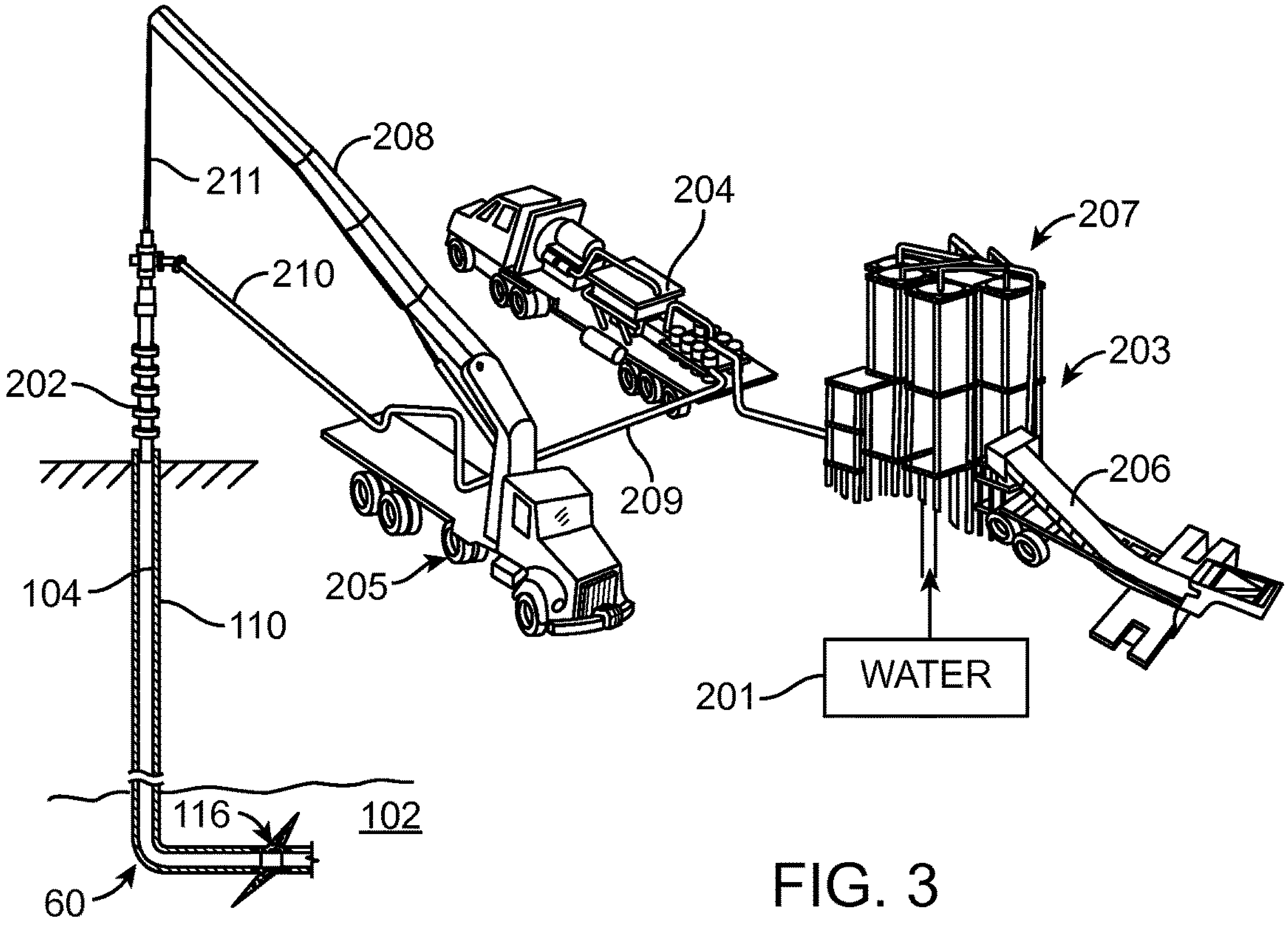


FIG. 2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211
204
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104
110
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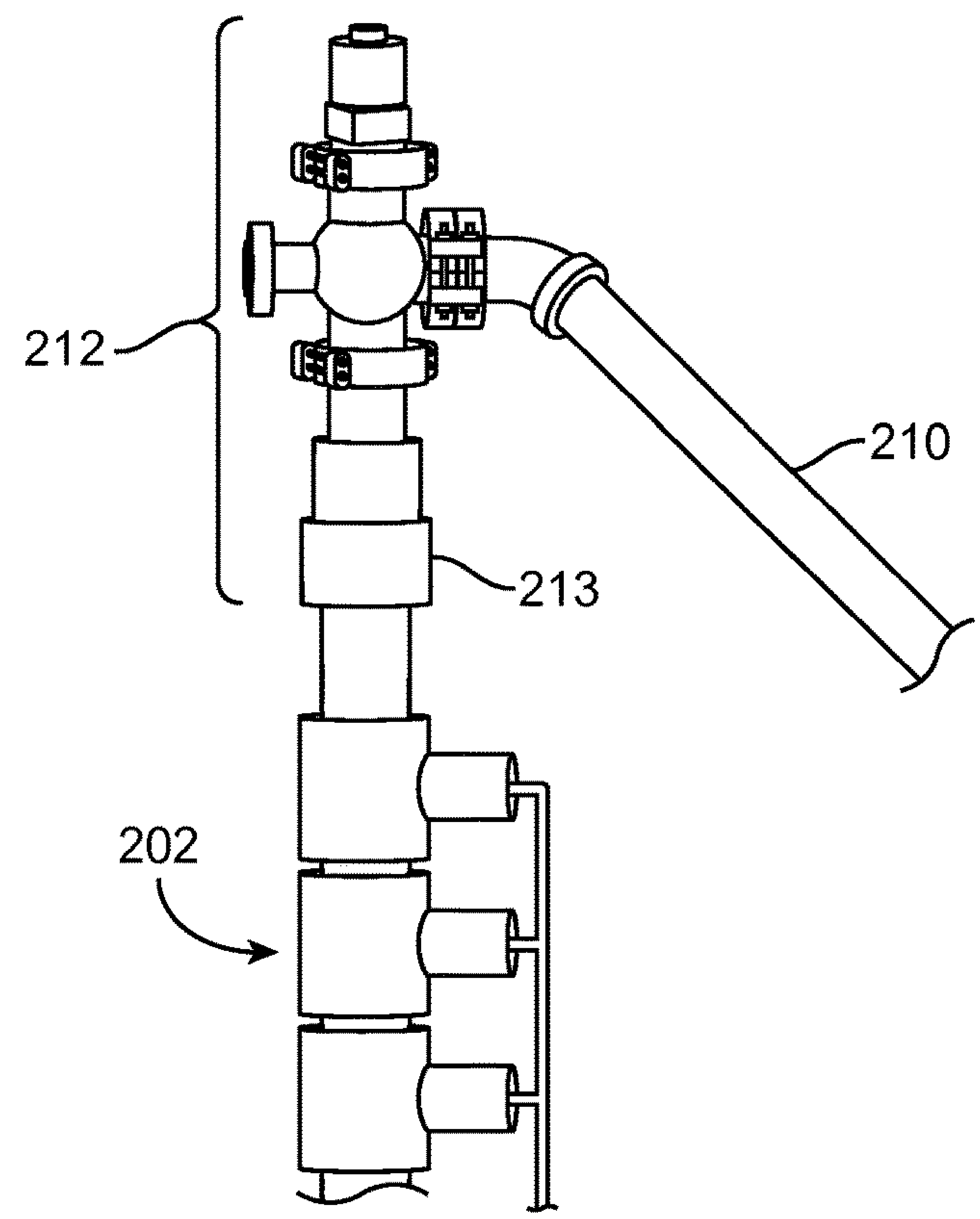
116
102
60

FIG. 3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210
213
202

FIG. 4

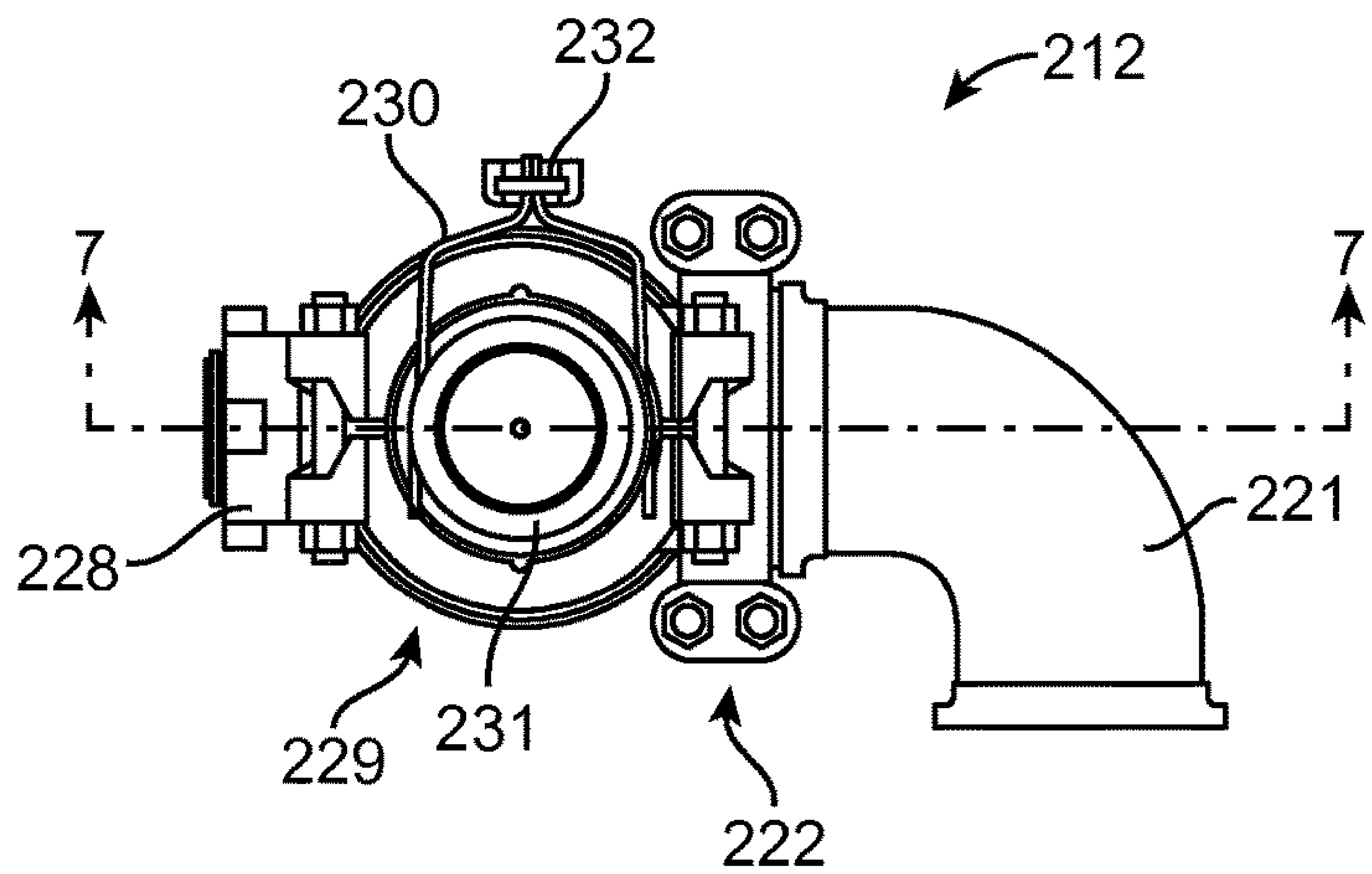

FIG. 5

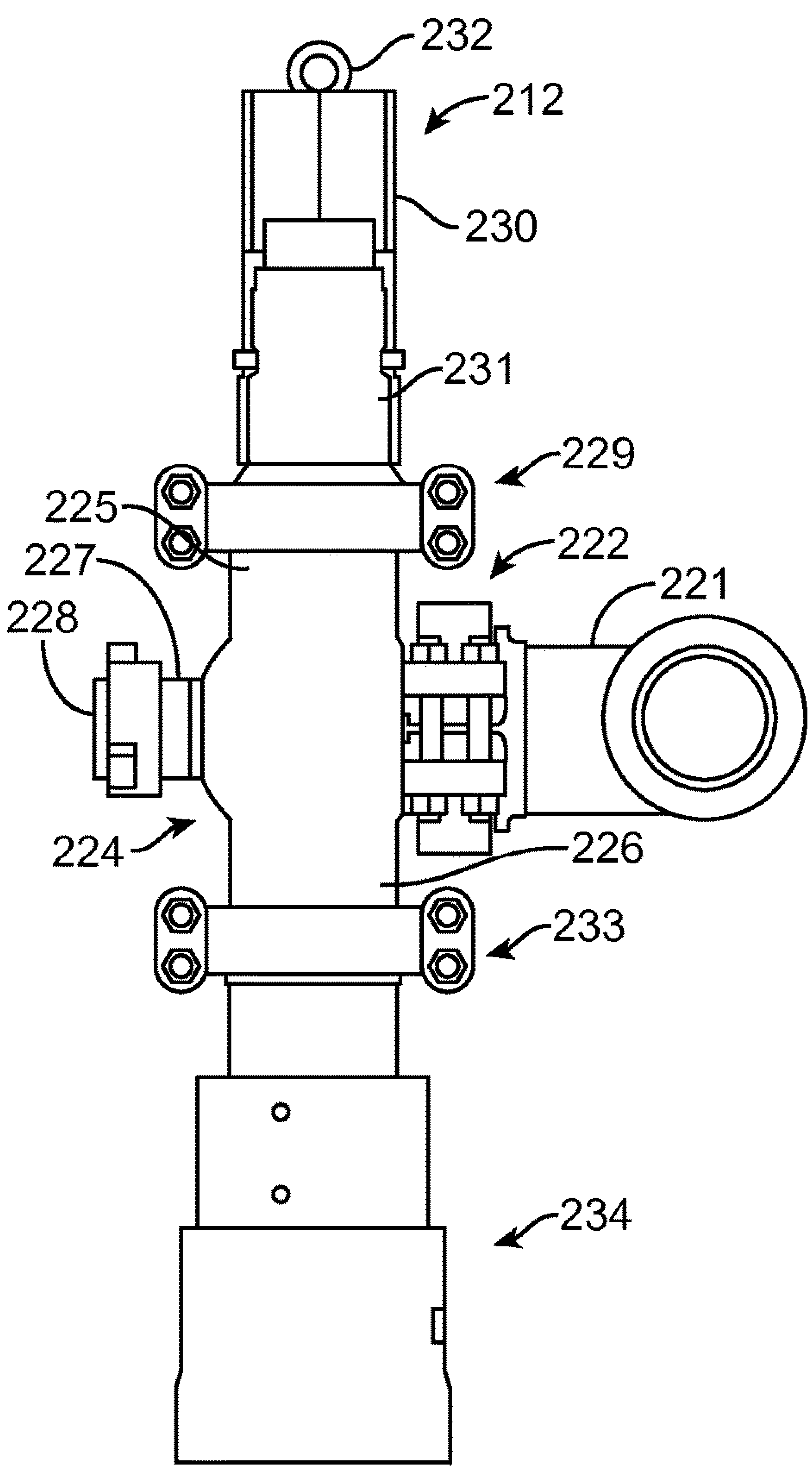

FIG. 6

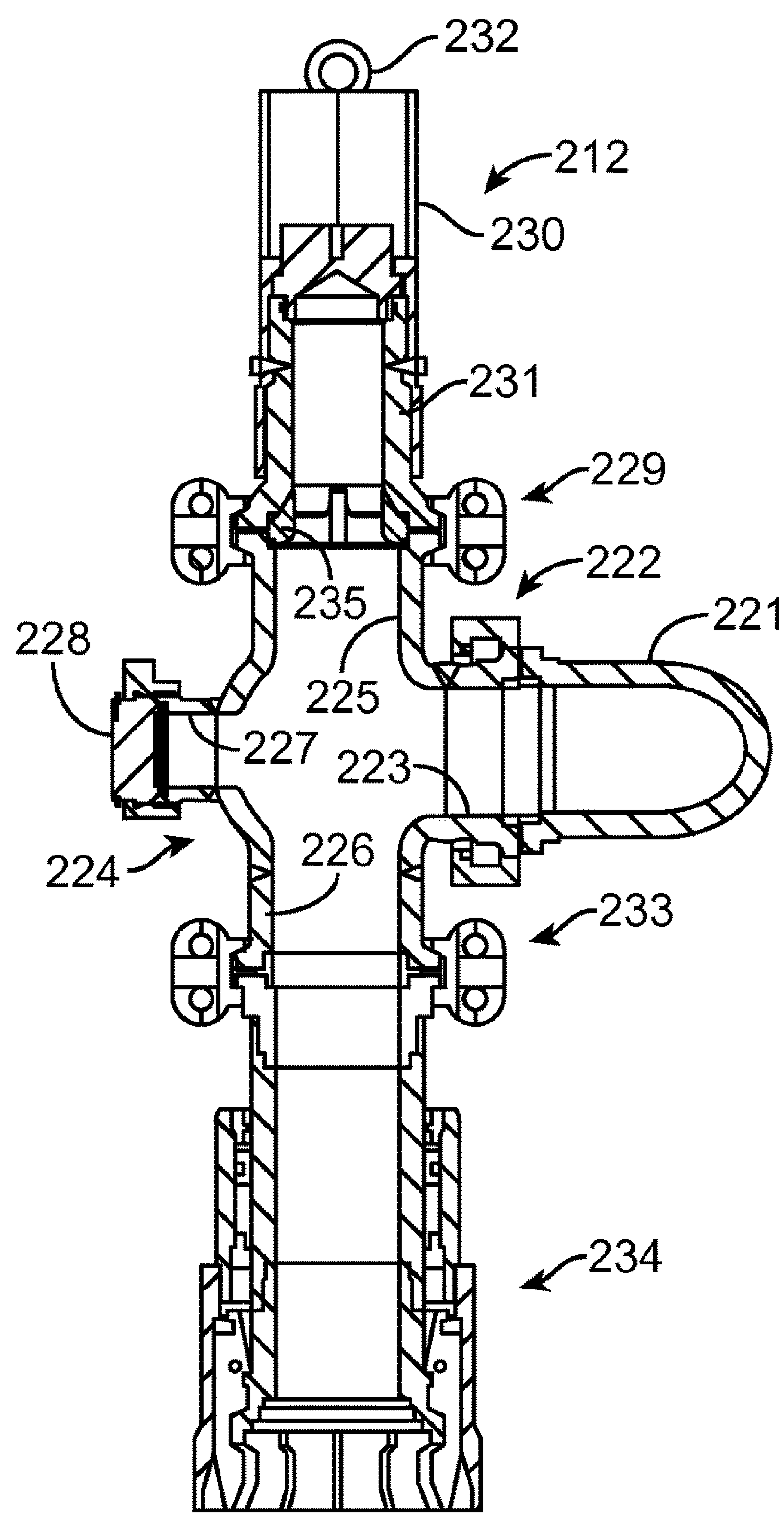

FIG. 7

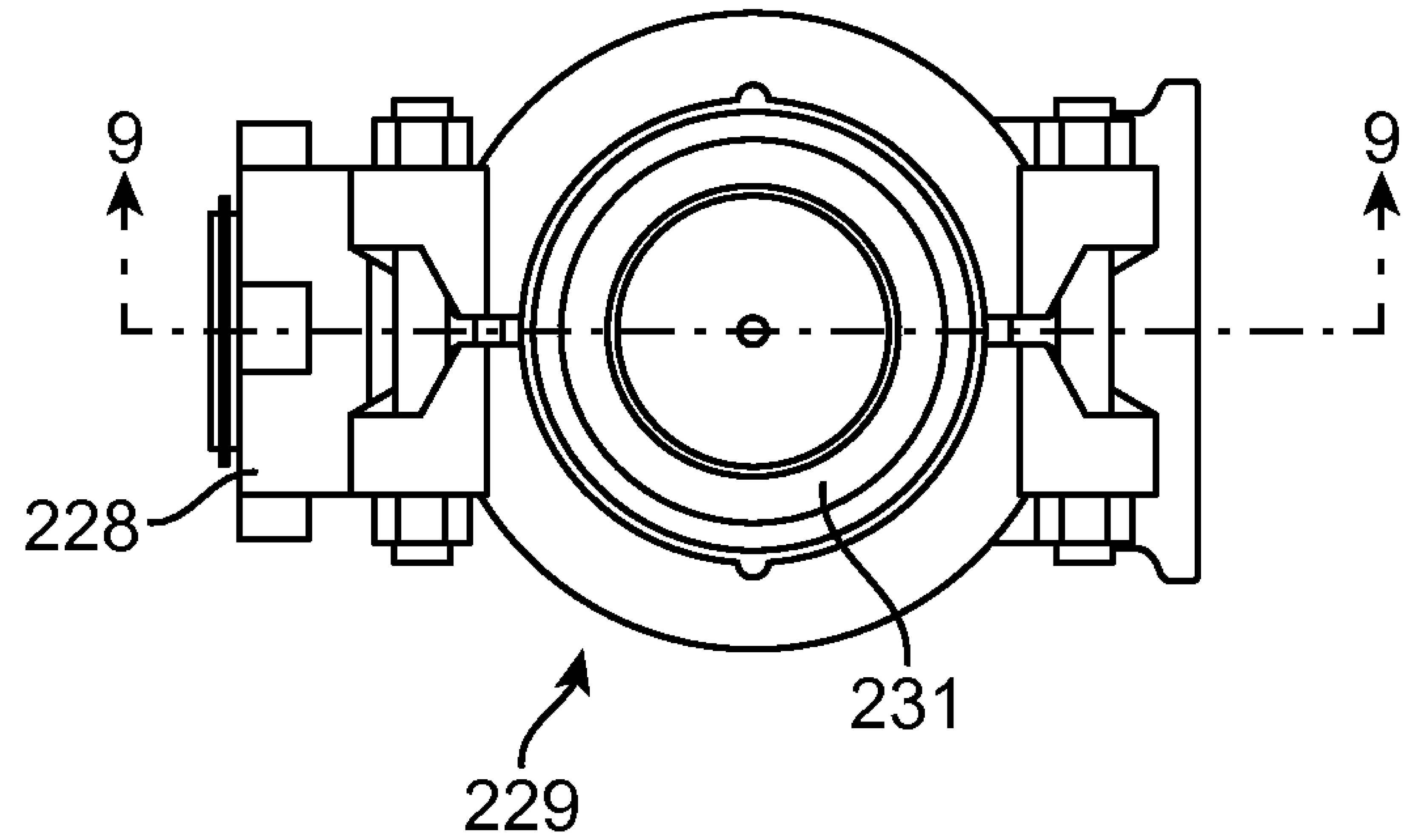

FIG. 8

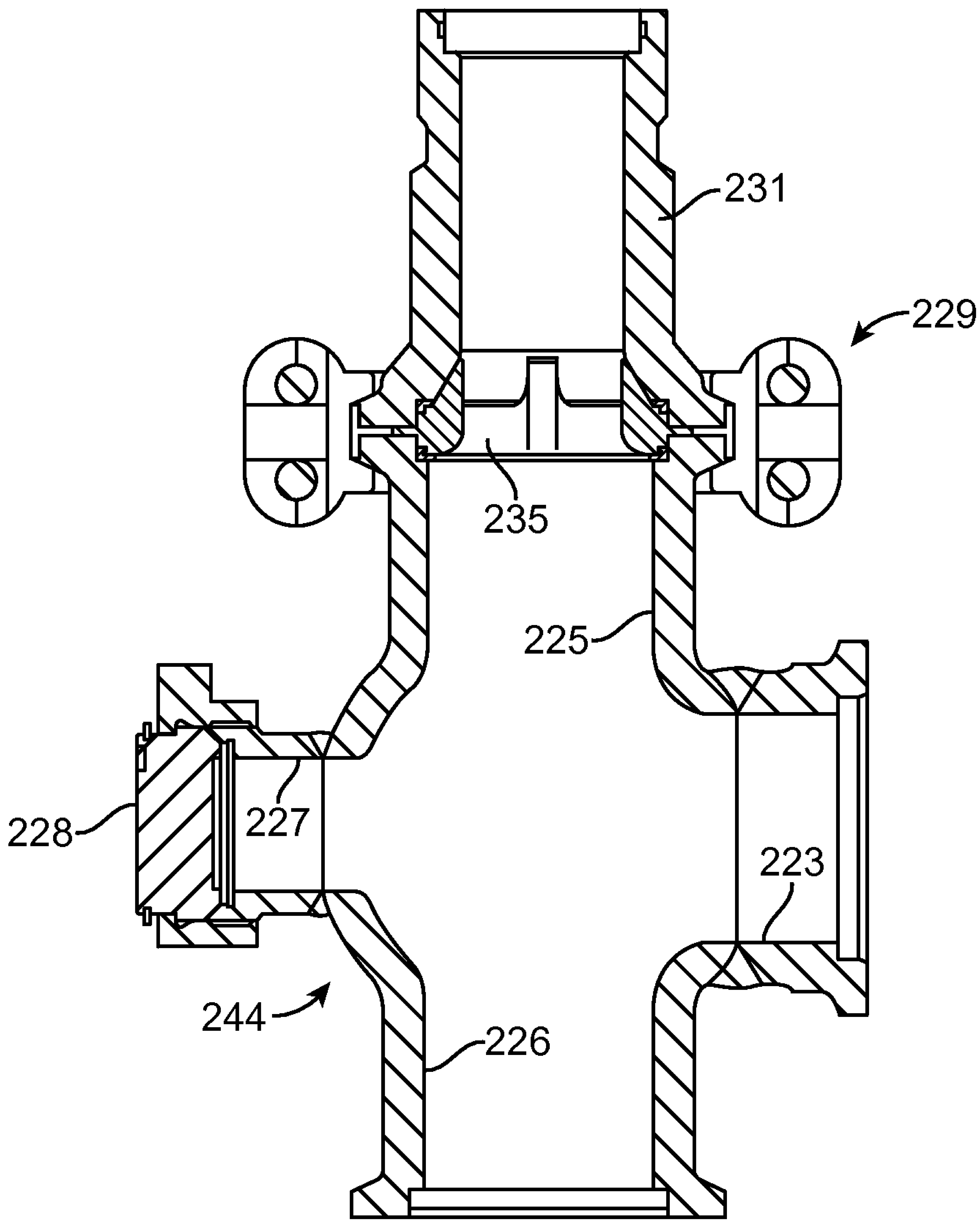

FIG. 9

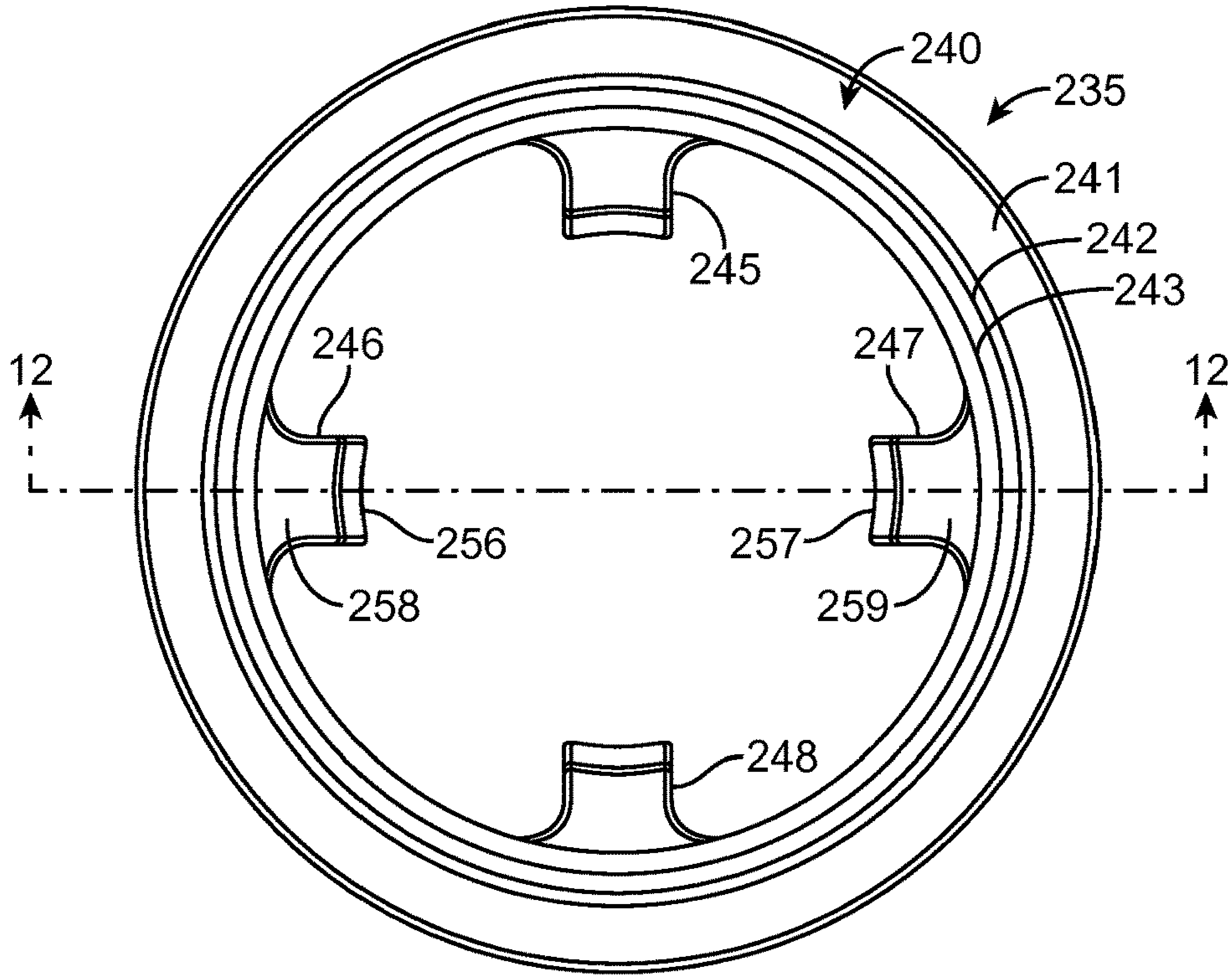

FIG. 10

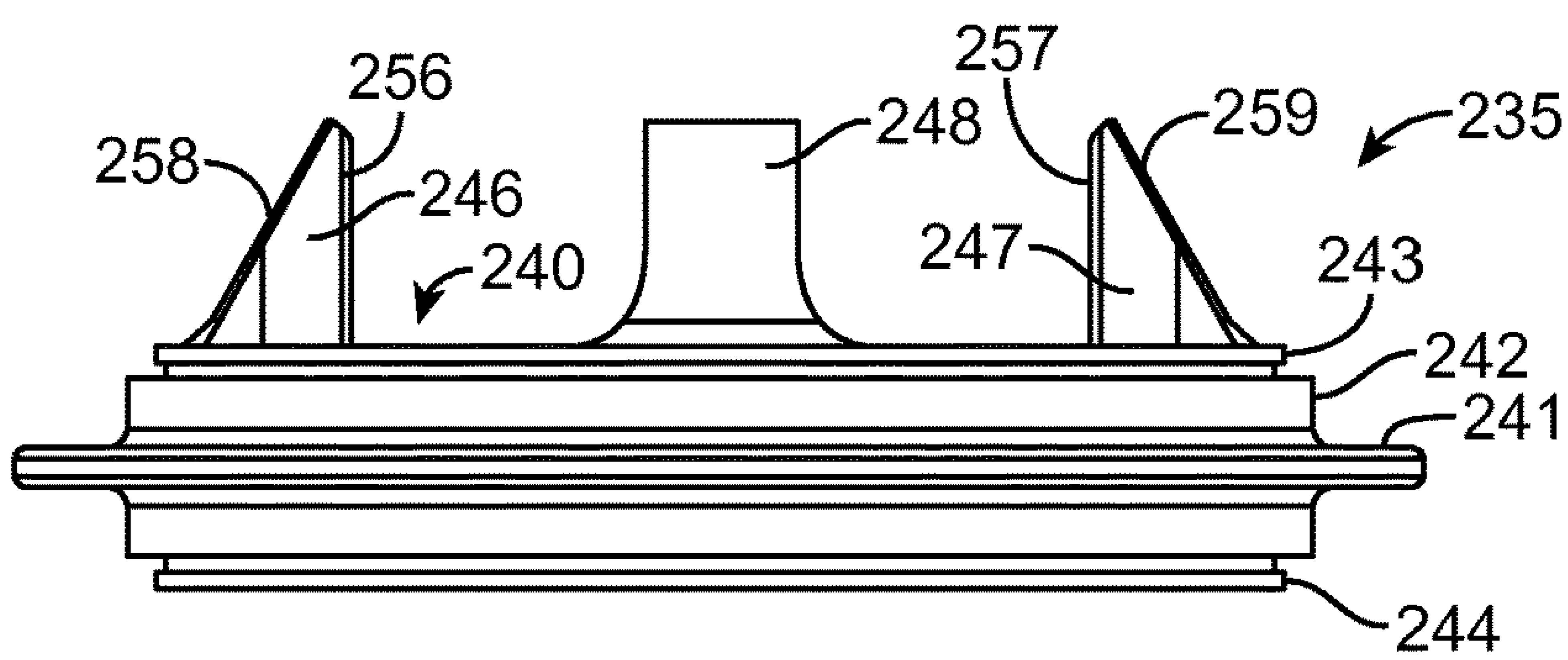

FIG. 11

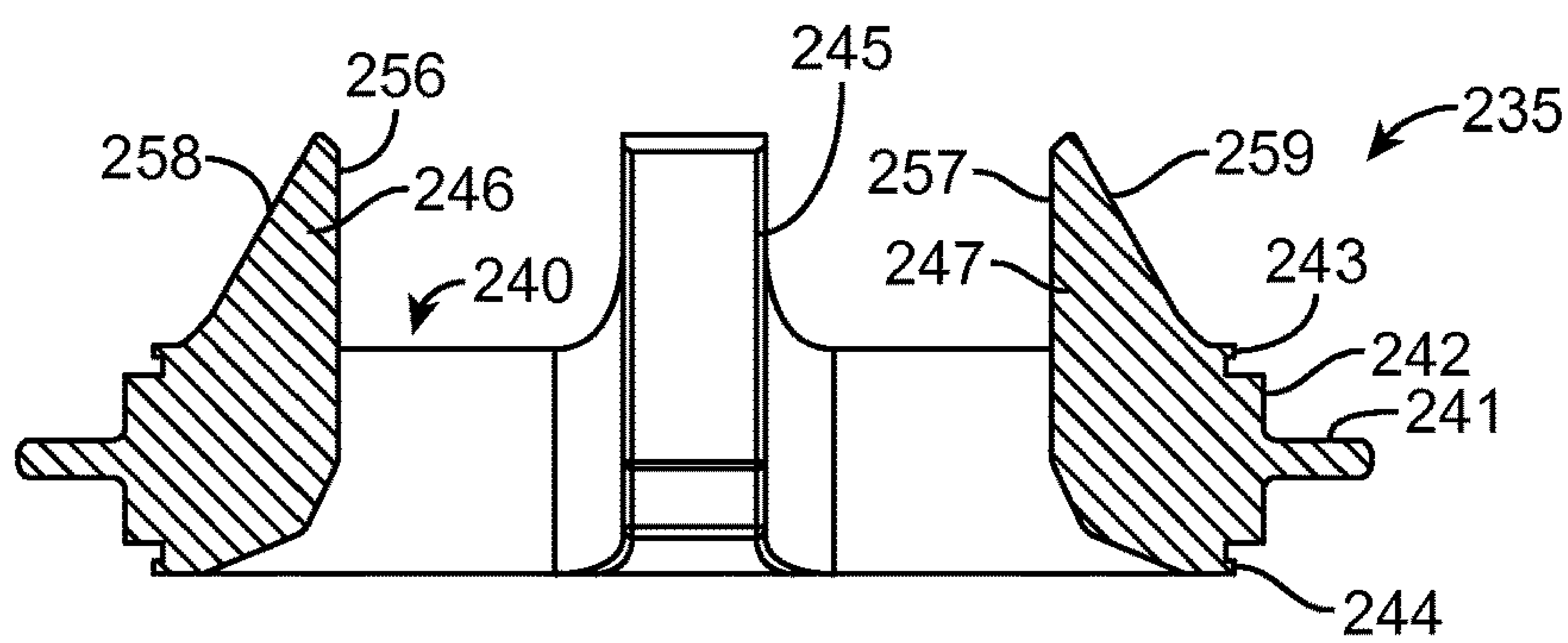

FIG. 12

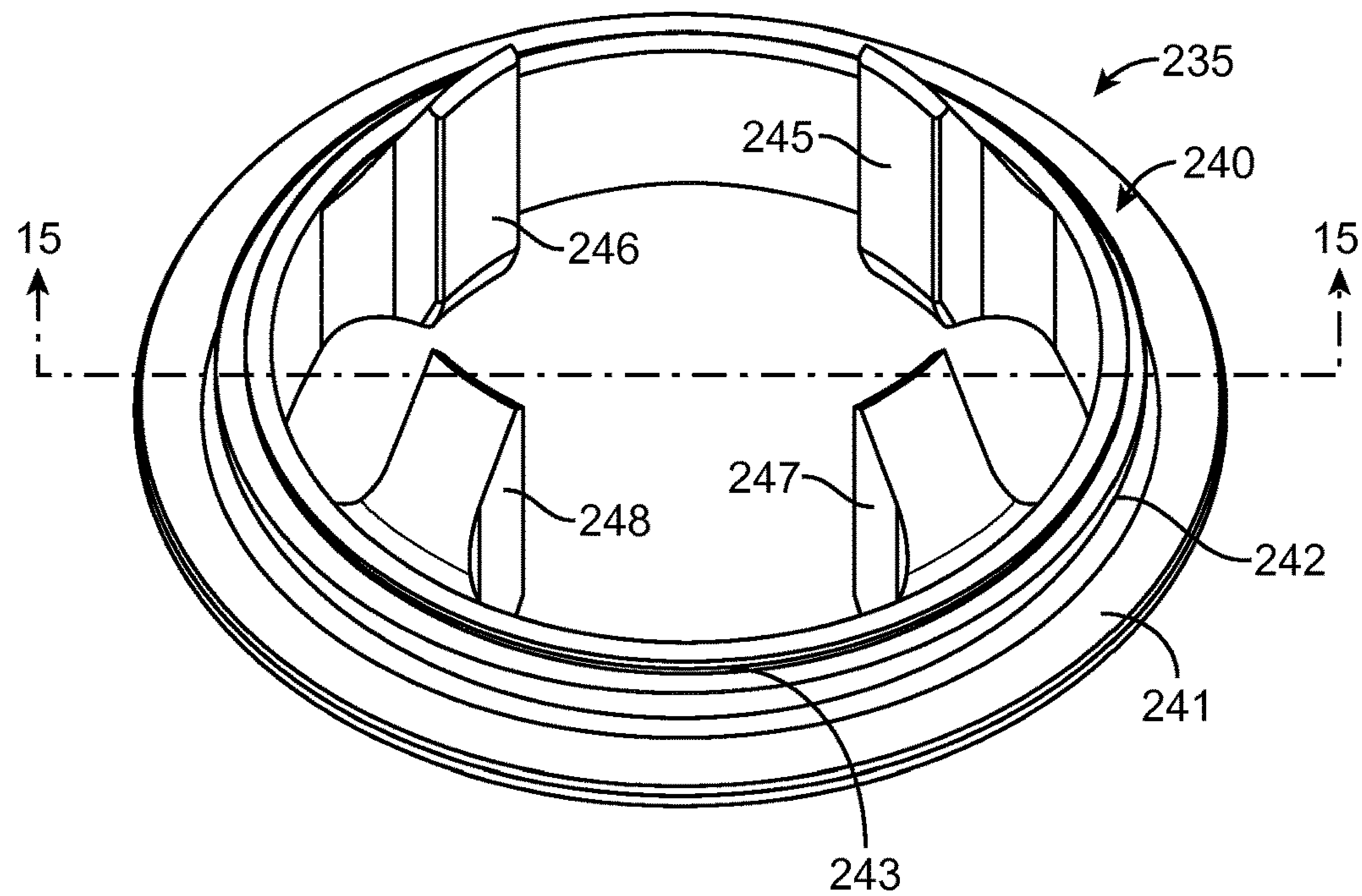

FIG. 13

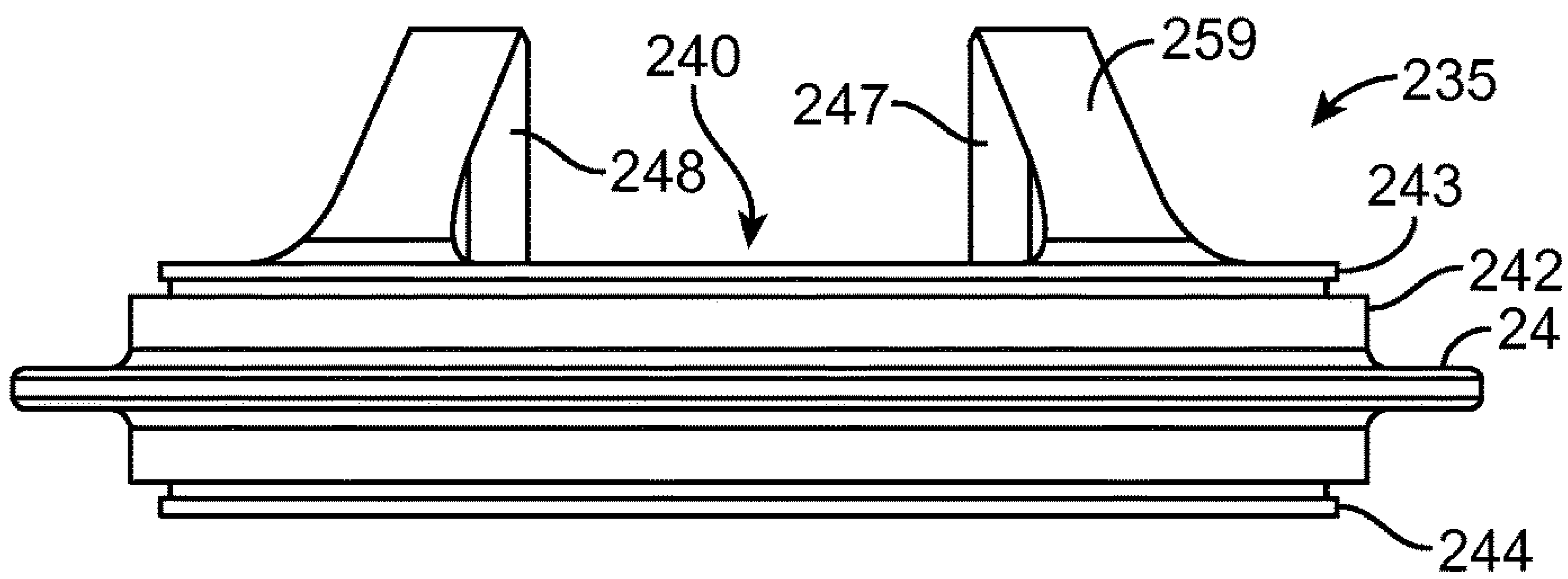

FIG. 14

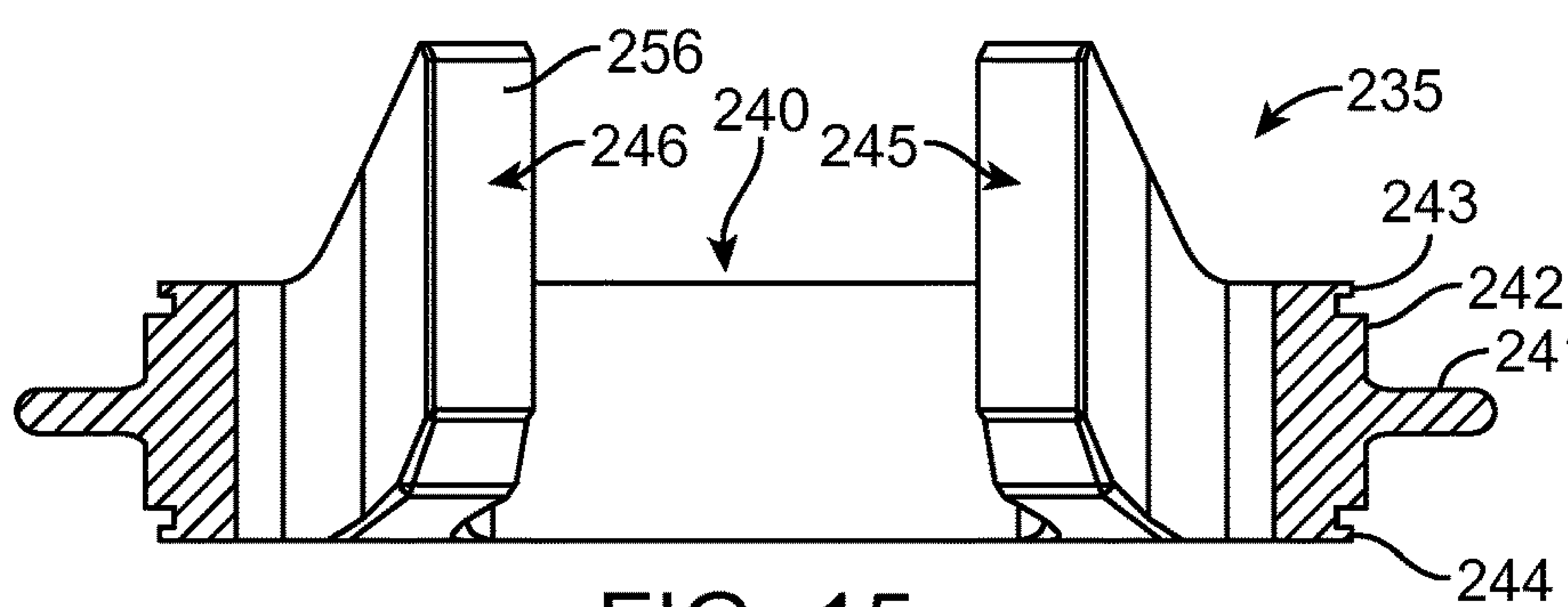

FIG. 15

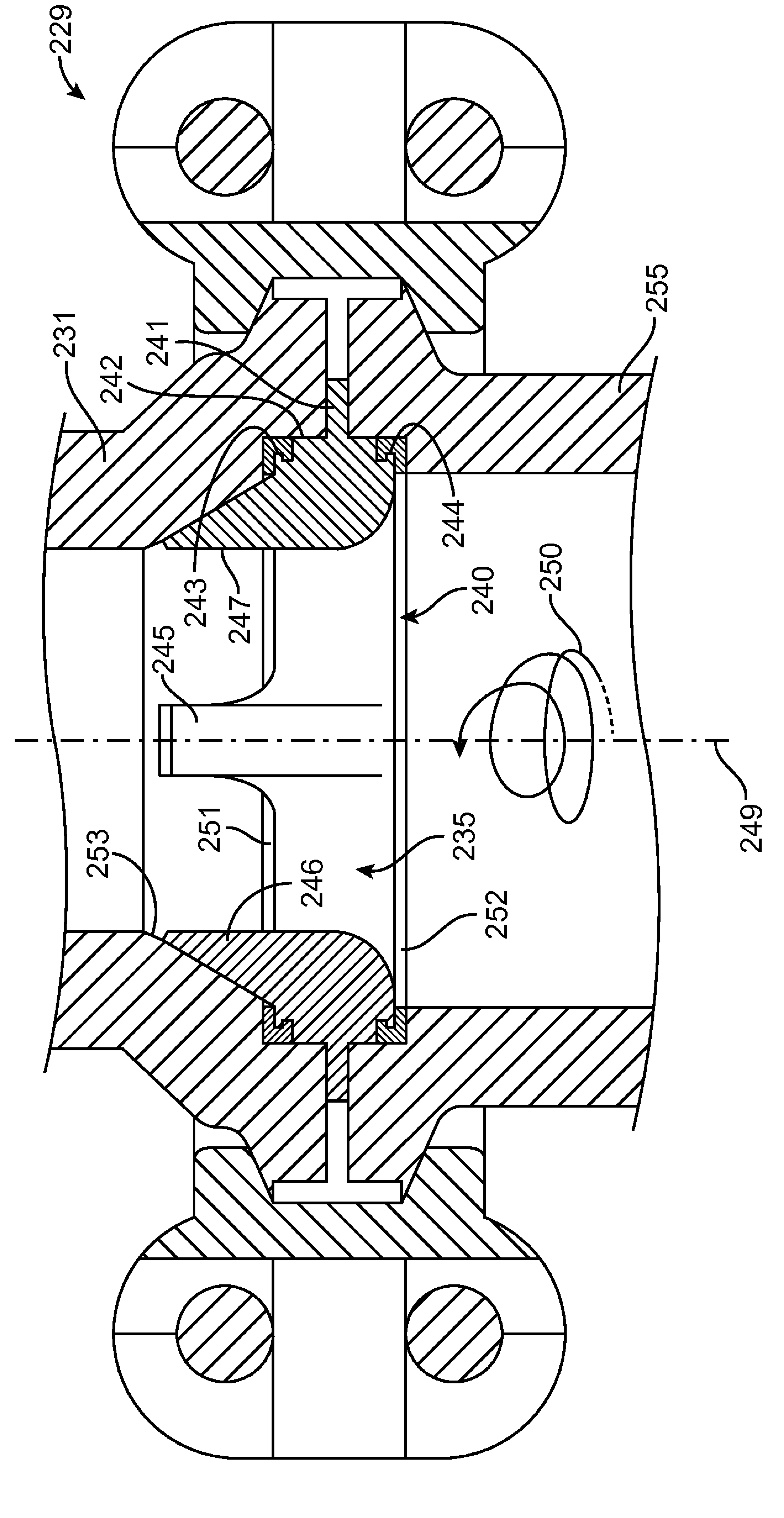
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FIG. 16

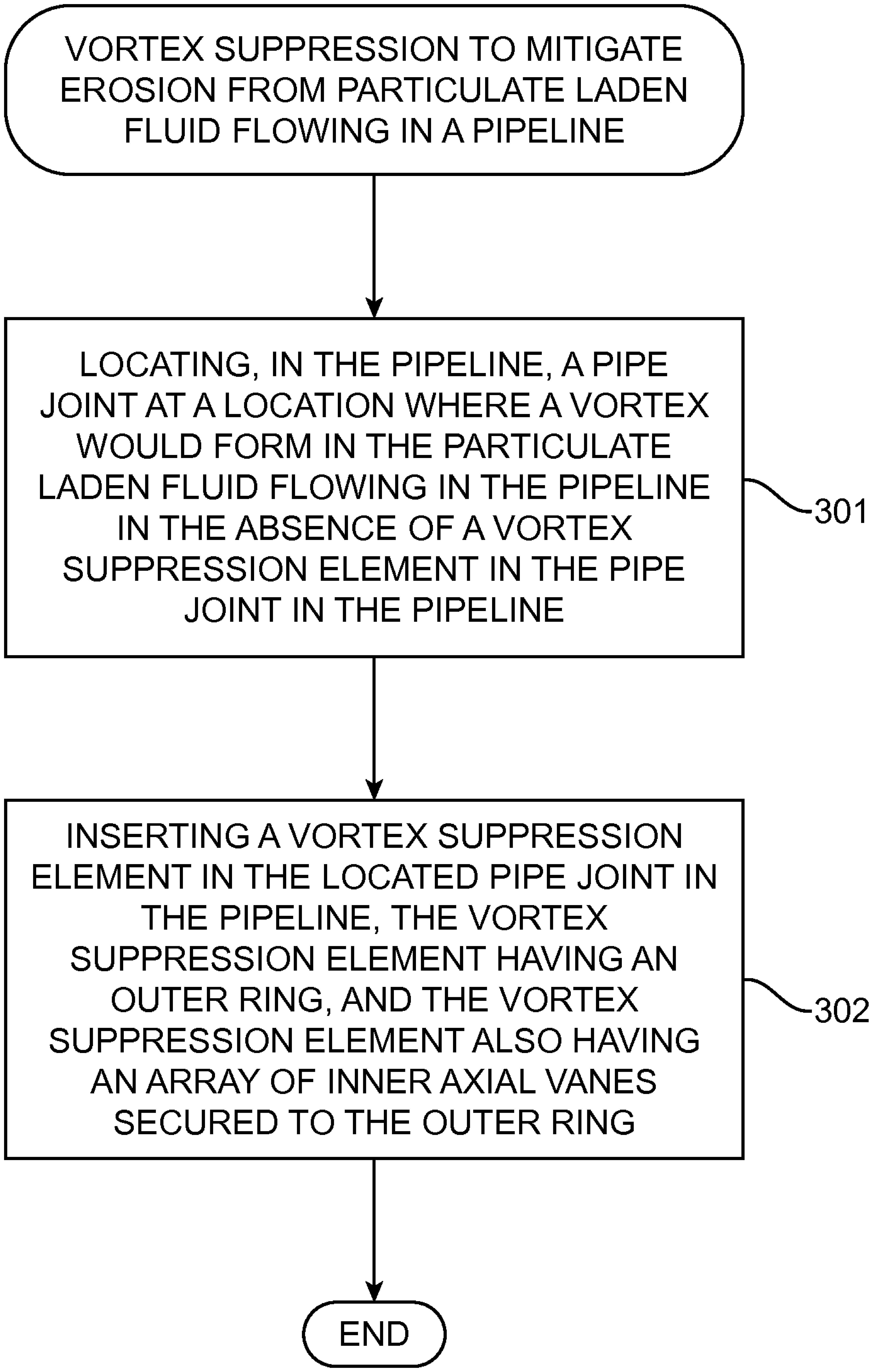
VORTEX SUPPRESSION TO MITIGATE EROSION FROM PARTICULATE LADEN FLUID FLOWING IN A PIPELINE
LOCATING, IN THE PIPELINE, A PIPE JOINT AT A LOCATION WHERE A VORTEX WOULD FORM IN THE PARTICULATE LADEN FLUID FLOWING IN THE PIPELINE IN THE ABSENCE OF A VORTEX SUPPRESSION ELEMENT IN THE PIPE JOINT IN THE PIPELINE
301
INSERTING A VORTEX SUPPRESSION ELEMENT IN THE LOCATED PIPE JOINT IN THE PIPELINE, THE VORTEX SUPPRESSION ELEMENT HAVING AN OUTER RING, AND THE VORTEX SUPPRESSION ELEMENT ALSO HAVING AN ARRAY OF INNER AXIAL VANES SECURED TO THE OUTER RING
302
END

FIG. 17

PARTICULATE LADEN FLUID VORTEX EROSION MITIGATION

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a national stage entry of PCT/US2015/040778 filed Jul. 16, 2015, said application is expressly incorporated herein in its entirety.

FIELD

The subject matter herein generally relates to the transport of particle laden fluid through pipes.

BACKGROUND

The transport of particle laden fluid through pipes at high pressures and high flow rates has become a common occurrence during hydraulic fracturing of subterranean hydrocarbon containing formations penetrated by well bores. Typically a fracturing fluid such as a gelled aqueous fluid is pumped into the formation at a rate and pressure such that fractures are created and extended therein. A propping material such as sand is typically deposited in the fractures so that they are prevented from completely closing to provide flow passages through which hydrocarbons readily flow to the well bore.

Presently there is commercially available equipment transportable via truck to a remote well site for rapid on-site assembly and connection to an on-site water source for the production of fracturing fluid and injection of the fracturing fluid into a well head. The equipment may produce and inject the fracturing fluid into the well head at a pressure up to 10,000 psi (69,000 kPa) and a flow rate up to 100 barrels per minute (bpm) thorough pipe having a nominal internal diameter of seven inches (15.8 cm).

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagram illustrating an example of a fracturing system that may be used in accordance with certain embodiments of the present disclosure;

FIG. **2** is a diagram illustrating an example of a subterranean formation in which a fracturing operation may be performed in accordance with certain embodiments of the present disclosure;

FIG. **3** is a pictorial diagram of equipment assembled at a well site for on-site production and injection of fracturing fluid into a well head;

FIG. **4** is a pictorial diagram of a hub transition assembly of a Wellhead Connection Unit (WCU) mounted on the well head of FIG. **3**;

FIG. **5** is a top view of the hub transition assembly;

FIG. **6** is a side view of the hub transition assembly;

FIG. **7** is a lateral section view of the hub transition assembly along section line **7-7** in FIG. **5**;

FIG. **8** is a top view of a hub adapter and cross-connector sub-assembly of the hub transition assembly;

FIG. **9** is a side cross-section view of the hub adapter and cross-connector sub-assembly along section line **9-9** in FIG. **8**;

FIG. **10** is a top view of a vortex suppression element introduced in FIG. **9**;

FIG. **11** is a side view of the vortex suppression element;

FIG. **12** is a cross-section view of the vortex suppression element along section line **12-12** in FIG. **10**;

FIG. **13** is an oblique view of the vortex suppression element;

FIG. **14** is another side view of the vortex suppression element;

FIG. **15** is a cross-section view of the vortex suppression element along section line **15-15** in FIG. **13**;

FIG. **16** is an enlarged view of the pipe joint containing the vortex suppression element as introduced in FIG. **9**; and

FIG. **17** is a flowchart showing a method of using the vortex suppression element.

DETAILED DESCRIPTION

It will be appreciated that for simplicity and clarity of illustration, where appropriate, reference numerals have been repeated among the different figures to indicate corresponding or analogous elements. In addition, numerous specific details are set forth in order to provide a thorough understanding of the embodiments described herein. However, it will be understood by those of ordinary skill in the art that the embodiments described herein can be practiced without these specific details. In other instances, methods, procedures and components have not been described in detail so as not to obscure the related relevant feature being described. Also, the description is not to be considered as limiting the scope of the embodiments described herein. The drawings are not necessarily to scale and the proportions of certain parts have been exaggerated to better illustrate details and features of the present disclosure.

In the following description, terms such as "upper," "upward," "lower," "downward," "above," "below," "downhole," "uphole," "longitudinal," "lateral," and the like, as used herein, shall mean in relation to the bottom or furthest extent of, the surrounding wellbore even though the wellbore or portions of it may be deviated or horizontal. Correspondingly, the transverse, axial, lateral, longitudinal, radial, etc., orientations shall mean orientations relative to the orientation of the wellbore or tool.

The term "outside" refers to a region that is beyond the outermost confines of a physical object. The term "inside" indicate that at least a portion of a region is partially contained within a boundary formed by the object. The term "substantially" is defined to be essentially conforming to the particular dimension, shape or other word that substantially modifies, such that the component need not be exact. For example, substantially cylindrical means that the object resembles a cylinder, but can have one or more deviations from a true cylinder.

The term "radially" means substantially in a direction along a radius of the object, or having a directional component in a direction along a radius of the object, even if the object is not exactly circular or cylindrical. The term "axially" means substantially along a direction of the axis of the object.

Wells in certain geographic locations such as in shale formations may require an initial fracturing to be economically productive. Wells that have been initially fractured are often successfully restimulated by refracturing. The initial fracturing and the refracturing involve injection of fracturing fluid into the well bore. In most cases, the fracturing fluids include particulate proppant material sized to enter into and prop open fractures created in the subterranean formation surrounding the well bore by injecting the fracturing fluid under pressure into the well bore. For example, 100 mesh sand, 40/70 and 30/50 sieve sizes, is commonly used as proppant material.

The exemplary methods and compositions disclosed herein may directly or indirectly affect one or more components or pieces of equipment associated with the preparation, delivery, recapture, recycling, reuse, and/or disposal of the disclosed compositions. For example, and with reference to FIG. **1**, the disclosed methods and compositions may directly or indirectly affect one or more components or pieces of equipment associated with an exemplary fracturing system **10**, according to one or more embodiments. In certain instances, the system **10** includes a fracturing fluid producing apparatus **20**, a fluid source **30**, a proppant source **40**, and a pump and blender system **50**, and the system **10** resides at the surface at a well site where a well **60** is located. In certain instances, the fracturing fluid producing apparatus **20** combines a gel pre-cursor with fluid (e.g., liquid or substantially liquid) from fluid source **30**, to produce a hydrated fracturing fluid that is used to fracture the formation. The hydrated fracturing fluid can be a fluid for ready use in a fracture stimulation treatment of the well **60** or a concentrate to which additional fluid is added prior to use in a fracture stimulation of the well **60**. In other instances, the fracturing fluid producing apparatus **20** can be omitted and the fracturing fluid sourced directly from the fluid source **30**. In some instances, the fracturing fluid may comprise water, a hydrocarbon fluid, a polymer gel, foam, air, wet gases and/or other fluids.

The proppant source **40** can include a proppant for combination with the fracturing fluid. The system **10** may also include additive source **70** that provides one or more additives (e.g., gelling agents, weighting agents, self-degrading particulates, and/or other optional additives) to alter the properties of the fracturing fluid. For example, the other additives **70** can be included to reduce pumping friction, to reduce or eliminate the fluid's reaction to the geological formation in which the well is formed, to operate as surfactants, and/or to serve other functions.

The pump and blender system **50** receives the fracturing fluid and combines it with other components, including proppant from the proppant source **40** and/or additional fluid from the additives **70**. The resulting mixture may be pumped down the well **60** under a pressure sufficient to create or enhance one or more fractures in a subterranean zone, for example, to stimulate production of fluids from the zone. Notably, in certain instances, the fracturing fluid producing apparatus **20**, fluid source **30**, and/or proppant source **40** may be equipped with one or more metering devices (not shown) to control the flow of fluids, proppants, and/or other compositions to the pumping and blender system **50**. Such metering devices may permit the pumping and blender system **50** can source from one, some or all of the different sources at a given time, and may facilitate the preparation of fracturing fluids in accordance with the present disclosure using continuous mixing or "on-the-fly" methods. Thus, for example, the pumping and blender system **50** can provide just fracturing fluid into the well at some times, just proppants at other times, just additives at other times, and combinations of those components at yet other times.

FIG. **2** shows the well **60** during a fracturing operation in a portion of a subterranean formation of interest **102** surrounding a well bore **104**. The well bore **104** extends from the surface **106**, and the fracturing fluid **108** is applied to a portion of the subterranean formation **102** surrounding the horizontal portion of the well bore. Although shown as vertical deviating to horizontal, the well bore **104** may include horizontal, vertical, slant, curved, and other types of well bore geometries and orientations, and the fracturing treatment may be applied to a subterranean zone surrounding any portion of the well bore. The well bore **104** can include a casing **110** that is cemented or otherwise secured to the well bore wall. The well bore **104** can be uncased or include uncased sections. Perforations can be formed in the casing **110** to allow fracturing fluids and/or other materials to flow into the subterranean formation **102**. In cased wells, perforations can be formed using shape charges, a perforating tool, hydro-jetting and/or other tools.

The well **60** is shown with a work string **112** depending from the surface **106** into the well bore **104**. The pump and blender system **50** is coupled a work string **112** to pump the fracturing fluid **108** into the well bore **104**. The working string **112** may include coiled tubing, jointed pipe, and/or other structures that allow fluid to flow into the well bore **104**. The working string **112** can include flow control devices, bypass valves, ports, and or other tools or well devices that control a flow of fluid from the interior of the working string **112** into the subterranean zone **102**. For example, the working string **112** may include ports adjacent the well bore wall to communicate the fracturing fluid **108** directly into the subterranean formation **102**, and/or the working string **112** may include ports that are spaced apart from the well bore wall to communicate the fracturing fluid **108** into an annulus in the well bore between the working string **112** and the well bore wall.

The working string **112** and/or the well bore **104** may include one or more sets of packers **114** that seal the annulus between the working string **112** and well bore **104** to define an interval of the well bore **104** into which the fracturing fluid **108** will be pumped. FIG. **2** shows two packers **114**, one defining an uphole boundary of the interval and one defining the downhole end of the interval. When the fracturing fluid **108** is introduced into well bore **104** (e.g., in FIG. **2**, the area of the well bore **104** between packers **114**) at a sufficient hydraulic pressure, one or more fractures **116** may be created in the subterranean zone **102**. The proppant particulates in the fracturing fluid **108** may enter the fractures **116** where they may remain after the fracturing fluid flows out of the well bore. These proppant particulates may "prop" fractures **116** such that fluids may flow more freely through the fractures **116**.

While not specifically illustrated herein, the disclosed methods and compositions may also directly or indirectly affect any transport or delivery equipment used to convey the compositions to the fracturing system **10** such as, for example, any transport vessels, conduits, pipelines, trucks, tubulars, and/or pipes used to fluidically move the compositions from one location to another, any pumps, compressors, or motors used to drive the compositions into motion, any valves or related joints used to regulate the pressure or flow rate of the compositions, and any sensors (i.e., pressure and temperature), gauges, and/or combinations thereof, and the like.

As shown in FIG. **3**, equipment has been transported via truck to a remote well site for rapid on-site assembly and connection to an on-site water source **201** for the production of fracturing fluid and injection of the fracturing fluid into a well head **202**. In this example, the equipment includes a proppant management system **203**, a pumping unit **204**, and a well head connection unit **205**. In other examples, the equipment may include more than one pumping unit for increasing the flow rate, and additional units such as one or more polymer blenders for adding polymer gel to the fracturing fluid. The equipment may produce and inject the fracturing fluid into the well head at a pressure up to 10,000 psi (69,000 kPa) and a flow rate up to 100 barrels per minute (bpm) thorough pipe having a nominal internal diameter of seven inches (15.8 cm).

The proppant management system **203** has a conveyor belt **206** for receiving proppant dumped onto the conveyor belt, and for conveying the proppant into hoppers **207**. The proppant management system **203** may then selectively feed the proppant into a flow of water from the water source **201** to produce fracturing fluid. The pumping unit **204** pumps the fracturing fluid from the proppant management system **203** to the well head connection unit **205**.

The well head connection unit **205** is comprised of a flat-bed truck **208** configured as a crane having a telescoping box boom **208**. The flat-bed truck also carries an articulated pipeline including an inlet pipe segment **209** and an outlet pipe segment **210**. The distal end of the boom **208** supports a load line **211** that can be connected to the distal end of the inlet pipe segment **208** to elevate, translate, and lower the distal end of the inlet pipe segment **208** onto an outlet pipe connector of the pumping unit **204**. As shown in FIG. **3**, the load line **211** is connected to the distal end of the outlet pipe segment **210**, and has been used to elevate, translate, and lower the distal end of the outlet pipe segment onto the well head **202**.

FIG. **4** shows details of the connection of the distal end of the outlet pipe segment **110** to the well head **202**. The distal end of the outlet pipe segment **110** carries a hub transition assembly **212**. The bottom of the hub transition assembly **212** is the female part of a collet pipe connector **213** permitting rapid connection and disconnection of the hub transition assembly **212** from a hub that is the male part of the collet pipe connector **213** at the top of the well head **202**. Once the collet pipe connection has been made, fracturing fluid under high pressure may flow from the outlet pipe segment **210** of the well head connection unit (**205** in FIG. **1**) into the hub transition assembly **212**, and down through the hub transition assembly **210** and down through the well head **202** and into the subterranean well bore.

FIGS. **5**, **6**, and **7** show details of the hub transition assembly **212**. The hub transition assembly **212** has a 90 degree elbow **221** for connecting the hub transition assembly to the outlet pipe segment (**210** in FIGS. **3** and **4**) of the well head connection unit (**205** in FIG. **3**). A clamp **222** connects the elbow **221** to a first side port (**223** in FIG. **7**) of a multi-port pipe connector **224** of the hub transition assembly **212**. The multi-port pipe connector **224** has a top port **225**, a bottom port **226**, and a second side port **227**. The second side port **227** is opposite from the first side port to provide an access port for access to the first side port and into the elbow **221**. Normally the second side port **227** is closed by a cap **228** that screws onto the second side port **227**. A top clamp **229** connects a well access hub adapter (**231** in FIG. **7**) onto the top port **225** of the multi-port connector **224**. A lifting bracket **230** secures an eyelet **232** to the hub adapter **231**. The eyelet **232** provides an attachment point for the load line (**211** in FIG. **3**). The top port **225** and the hub adapter **231** can be used to enable a wire-line tool to access the well bore through the top port. A bottom clamp **233** connects the female part **234** of the collet connector (**213** in FIG. **4**) to the bottom port **226** of the multi-port connector **224**.

For example, the elbow **331**, first side port **223**, top port **225**, bottom port **226**, and collet connector **213** have a nominal internal diameter of seven inches (15.8 mm), the second side port has a nominal internal diameter of four inches (10.1 mm), and the hub adapter **231** provides a transition from an internal diameter of five inches (10.6 mm) to an internal diameter of seven inches (15.8 mm). The multi-port connector **224** has a spherical central region having an internal diameter of twelve inches (30.5 mm). The multi-port connector **224** could be considered a kind of seven inch "T" connector, or a kind of cross-connector.

In operation, fracturing fluid flows into the first side port **223** from the elbow **221**, and then down through the bottom port **226** to the female part **234** of the collet connector (**213** in FIG. **4**). When a flow rate of about 96 barrels per minute (bbm) has been used in the seven inch internal diameter piping, a vortex has been produced in the central region of the multi-port connector **224**. This vortex has caused a high rate of wear upon the internal wall of the hub adapter **231** and multi-port connector **224** due to abrasion of proppant against the internal wall. It has been discovered that this vortex can be suppressed by interposing a vortex suppression element (**235** in FIG. **7** and FIG. **9**) in the pipe joint between the hub adapter **231** and the top port **225** of the multi-port connector **224**. The vortex suppression element **235** can suppress the formation of a vortex despite the fact that there is no net axial flow of fracturing fluid through the top port **225**. Also, the vortex suppression element **235** can have an internal clearance no less than the five inch internal diameter of the hub adapter **231** so as not to interfere with the passage of wireline tools through the hub adapter.

FIGS. **10** to **15** show various views of the vortex suppression element **235**. The vortex suppression element **235** includes an outer ring **240** and an array of inner axial vanes **245**, **246**, **247**, **248** secured to the outer ring. For example, as shown, the axial vanes **245**, **246**, **247**, **248** are secured to an inner circumference of the outer ring and extend radially inward from the inner circumference of the outer ring. Neighboring ones of the inner axial vanes **245**, **246**, **247**, **248** are spaced by an angular increment around an inner circumference of the outer ring. For example, neighboring ones of the four axial vanes **245**, **246**, **247**, **248** in FIGS. **10** to **15** are spaced at a 90 degree increment around the inner circumference of the outer ring **245**. In other configurations, the array may include a different number of axial vanes, such as five axial vanes spaced at 72 degree increments around the inner circumference of the outer ring, or six axial vanes spaced at 60 degree increments around the inner circumference of the outer ring. The array of inner axial vanes may have four to six inner axial vanes.

In the examples of FIGS. **10** to **15**, the axial vanes **245**, **246**, **247**, and **248** are integral with the outer ring **235**. For example, the entire vortex suppression element **235** is machined from one steel sand casting. In other examples, the outer ring **235** could be one integral piece, and each axial vane could be another integral piece fastened to the outer ring **235**. For example, the axial vanes could be welded to the outer ring **235**.

In FIGS. **10** to **15**, the axial vanes **245**, **246**, **247**, **248** have upper ends protruding axially upward from the outer ring **245**. For example, the axially protruding portion of each axial vane include an inner surface (e.g. **256**, **257**) extending axially, and an outer surface (e.g. **258**, **259**) extending at an acute angle with respect to the inner surface.

In other configurations of the vortex suppression element **235**, the axial vanes could have lower ends protruding axially downward from the outer ring. In still other configurations, the axial vanes could have upper ends protruding axially upward from the outer ring, and also lower ends protruding axially downward from the outer ring.

In FIGS. **10** to **15**, the outer ring **240** has a disk-shaped rim **241** extending radially outward from a tubular body **242**. For example, as shown, the rim **241** is midway between an upper axial end and a lower axial end of the outer ring **242**, although in other configurations the rim **241** could be closer either to the lower axial end or closer to the upper axial end of the outer ring **242**.

In FIGS. **10** to **15**, the upper axial end of the outer ring **242** is formed with an upper circumferential lip **243**, and the lower axial end of the outer ring **242** is formed with a lower circumferential lip **244**.

FIG. **16** shows that the features of the vortex suppression element **235** described above conform to first and second pipe segments when the vortex suppression ring is sandwiched between neighboring ends of the first and second pipe segments at a joint connecting the neighboring ends of the first and second pipe segments. In particular, FIG. **16** is an expanded view of the joint in FIG. **9** connecting the lower end of the hub adapter **231** (i.e., the first pipe segment) to the upper end of the upper port **255** (i.e., the second pipe segment) of the multi-port connector (**244** in FIG. **9**). The vortex suppression element **235** suppresses formation of a vortex **250** that may form around a central longitudinal axis **249** at high flow rates of the fracturing fluid, such as flow rates of 96 barrels per minute or more, in the absence of the vortex suppression element.

In FIG. **16**, the clamp **229** clamps the disk-shaped rim **241** directly between the lower end of the hub adapter **231** and the upper end of the upper port **255**. The clamp **229** also clamps an upper annual seal **251** between the lower end of the hub adapter **231** and the upper axial end of the outer ring **240**, and clamps a lower annual seal **252** between the lower axial end of the outer ring **240** and the upper end of the upper port **255**.

The upper circumferential lip **243** is engaged in an internal annular groove in the upper annular seal **251**. Thus, the upper annular seal **251** may be fitted onto the upper axial end of the outer ring **240** so that the upper annular seal **251** is held in place by the upper circumferential lip **243**, prior to joining of the lower end of the hub adapter **231** to the upper end of the upper port **255**. In a similar fashion, the lower circumferential lip **244** is engaged in an internal annular groove in the lower annular seal **252**. Thus, the lower annular seal **252** may be fitted onto the lower axial end of the outer ring **240** so that it is held in place by the lower circumferential lip **244**, prior to joining of the lower end of the hub adapter **231** to the upper end of the upper port **255**. The annular seals **251**, **252**, for example, are elastomeric seals for low pressure operation, or ductile metal seals for high pressure operation.

In FIG. **16**, the axial vanes **245**, **246**, **247**, **248** protrude axially upward to conform to an internal conical surface **253** of the hub adapter **231**. This internal conical surface **253** provides a tapered transition from a smaller internal diameter of the upper part of the hub adapter **231** (e.g., five inches or 10.6 mm) to a larger internal diameter of the upper port **255** (e.g., seven inches or 15.8 cm). For example, the internal conical surface **253** has an acute angle of thirty degrees with respect to the central longitudinal axis **249**. In this example, the axial vanes **245**, **246**, **247** extend radially inward from the inner circumference of the outer ring **240** up to but no further inward than the internal diameter of the upper part of the hub adapter **231** so that the axial vanes do not physically interfere with any down-hole tools introduced into the well bore through the hub adapter. The bottom axial ends of the axial vanes **245**, **246**, **247** are rounded so that when a wireline tool is raised from the well bore, the tool is guided from the larger internal diameter of the upper port **255** to the smaller internal diameter of the hub adapter **231**.

Although the vortex suppression element **235** has been described with respect to the flow of fracturing fluid through a hub transition assembly of a well head connection unit, the vortex suppression element **235** may also be used for vortex suppression to mitigate erosion from other kinds of particulate laden fluid flowing through a pipeline. For example, the fluid could be ash and combustion gas products in a coal-fired power plant, or cement slurry in a facility for manufacturing cement blocks.

FIG. **17** shows a general method of using the vortex suppression element to mitigate erosion from particulate laden fluid flowing in a pipeline. In a first box **301**, the method includes locating, in the pipeline, a pipe joint at a location where a vortex would form in the particulate laden fluid flowing in the pipeline in the absence of a vortex suppression element in the pipe joint in the pipeline. For example, the location of such a pipe joint may be found by inspection of the internal surface of the pipeline for erosive wear. The inspection could be done by a video camera on a snake or pig run through the pipeline. If erosive wear is found, but such erosive wear is not found at the location of an existing pipe joint in the pipeline, then the pipeline could be cut at a location of the erosive wear and a pipe joint could be inserted at this location, for example by welding hubs to the ends of the pipeline at the location of the cut.

In a second box **302**, the vortex suppression element **235** is inserted in the located pipe joint in the pipeline. The vortex suppression element **235** has an outer ring, and the vortex suppression element also has an array of inner axial vanes secured to the outer ring. For example, the vortex suppression element **235** and a pair of seals **251**, **252** are clamped between the respective ends of the pipe segments of the located pipe joint.

Statements of the Disclosure Include:

Statement 1: An apparatus comprising: an outer ring; and an array of inner axial vanes secured to the outer ring.

Statement 2: The apparatus as in Statement 1, wherein the axial vanes are secured to an inner circumference of the outer ring and extend radially inward from the inner circumference of the outer ring.

Statement 3: The apparatus as in Statement 1 or 2, wherein the inner axial vanes are integral with the outer ring.

Statement 4: The apparatus according to any of the preceding Statements 1 to 3, wherein neighboring ones of the inner axial vanes are spaced by an angular increment around an inner circumference of the outer ring.

Statement 5: The apparatus according to any of the preceding Statements 1 to 4, wherein the array of inner axial vanes has four to six inner axial vanes.

Statement 6: The apparatus according to any of the preceding Statements 1 to 5, wherein the axial vanes protrude axially from the outer ring.

Statement 7: The apparatus according to any of the preceding Statements 1 to 6, wherein an axial protruding portion of each axial vane includes an inner surface extending axially and an outer surface extending at an acute angle with respect to the inner surface.

Statement 8: The apparatus according to any of the preceding Statements 1 to 7, wherein the outer ring has a tubular body and a disk-shaped rim extending radially outward from the tubular body.

Statement 9: The apparatus according to any of the preceding Statements 1 to 8, further comprising a pipe joint including a first pipe segment and a second pipe segment joined to the first pipe segment, and the disk-shaped rim is clamped in the pipe joint between an end of the first pipe segment and an end of the second pipe segment.

Statement 10: The apparatus according to any of the preceding Statements 1 to 9, wherein the outer ring has a first axial end and a first circumferential lip on the first axial end, and the outer ring has a second axial end and a second circumferential lip on the second axial end.

Statement 11: The apparatus according to any of the preceding Statements 1 to 10, further comprising a first annular seal engaging the first axial end of the outer ring and held to the first axial end of the outer ring by the first circumferential lip, and further comprising a second annular seal engaging the second axial end of the outer ring and held to the second axial end of the outer ring by the second circumferential lip.

Statement 12: The apparatus according to any of the preceding Statements 1 to 11, further comprising a pipe joint including a first pipe segment and a second pipe segment joined to the first pipe segment, and the outer ring is clamped in the pipe joint between an end of the first pipe segment and an end of the second pipe segment.

Statement 13: The apparatus according to the preceding Statement 12, wherein the second pipe segment is a first port of multi-port pipe connector.

Statement 14: The apparatus according to the preceding Statement 13, wherein the first pipe segment is a hub adapter for providing access to a well head of a subterranean well bore, and the first port is a top port of the multi-port pipe connector, and the multi-port pipe connector has a side port for inflow of fracturing fluid from a pump, and the multi-port pipe connector has a bottom port for outflow of the fracturing fluid to the well head.

Statement 15: The apparatus according to any of the preceding Statements 12 to 14, further comprising a first annular seal clamped between an end of the first pipe segment and a first axial end of the outer ring, and a second annular seal clamped between a second annular end of the outer ring and an end of the second pipe segment.

Statement 16: The apparatus according to any of the preceding Statements 12 to 15, wherein the first pipe segment has an internal diameter less than an internal diameter of the second pipe segment, and the axial vanes protrude radially inward from an inner circumference of the outer ring to the internal diameter of the first pipe segment.

Statement 17: The apparatus according to the preceding Statement 16, wherein the first pipe segment has a tapered transition from the end of the first pipe segment to the internal diameter of the first pipe segment, and the axial vanes conform to the tapered transition and protrude axially into the tapered transition.

Statement 18: The apparatus according to the preceding Statements 16 or 17, wherein the axial vanes protrude radially inward no further than the inner diameter of the first pipe segment.

Statement 19: A method of vortex suppression to mitigate erosion from particulate laden fluid flowing in a pipeline, the method comprising: (a) locating, in the pipeline, a pipe joint at a location where a vortex would form in the particulate laden fluid flowing in the pipeline in the absence of a vortex suppression element in the pipe joint in the pipeline; and (b) inserting, in the located pipe joint in the pipeline, a vortex suppression element in accordance with any of the preceding examples first to eighteenth.

Statement 20: The method according to statement 19, wherein the particulate laden fluid is fracturing fluid, the pipeline conveys the fracturing fluid from a pump to a well head of a subterranean well bore, the located pipe joint is a joint between a well access hub adapter and a top port of a multi-port pipe connector, and the multi-port pipe connector also has a side port for inflow of the fracturing fluid from the pump, and the multi-port pipe connector also has a bottom port for outflow of the fracturing fluid to the well head.

The embodiments shown and described above are only examples. Even though numerous characteristics and advantages of the present technology have been set forth in the foregoing description, together with details of the structure and function of the present disclosure, the disclosure is illustrative only, and changes may be made in the detail, especially in matters of shape, size and arrangement of the parts within the principles of the present disclosure to the full extent indicated by the broad general meaning of the terms used in the attached claims. It will therefore be appreciated that the embodiments described above may be modified within the scope of the appended claims.

What is claimed is:

1. An apparatus comprising:

(a) an outer ring with a first axial end and a first circumferential lip on the first axial end and a second axial end and a second circumferential lip on the second axial end;

(b) an array of inner axial vanes secured to the outer ring, the inner axial vanes protruding axially from the outer ring, each axial vane including an inner surface extending axially and an outer surface extending at an acute angle with respect to the inner surface; and (c)

a first annular seal engaging the first axial end of the outer ring and held to the first axial end of the outer ring by the first circumferential lip, and a second annular seal engaging the second axial end of the outer ring and held to the second axial end of the outer ring by the second circumferential lip.

2. The apparatus as claimed in claim **1**, wherein the axial vanes are secured to an inner circumference of the outer ring and extend radially inward from the inner circumference of the outer ring.

3. The apparatus as claimed in claim **1**, wherein the inner axial vanes are integral with the outer ring.

4. The apparatus as claimed in claim **1**, wherein neighboring ones of the inner axial vanes are spaced by an angular increment around an inner circumference of the outer ring.

5. The apparatus as claimed in claim **1**, wherein the array of inner axial vanes has four to six inner axial vanes.

6. The apparatus as claimed in claim **1**, wherein the outer ring has a tubular body and a disk-shaped rim extending radially outward from the tubular body.

7. The apparatus as claimed in claim **6**, further comprising a pipe joint including a first pipe segment and a second pipe segment joined to the first pipe segment, and the disk-shaped rim is clamped in the pipe joint between an end of the first pipe segment and an end of the second pipe segment.

8. The apparatus as claimed in claim **1**, further comprising a pipe joint including a first pipe segment and a second pipe segment joined to the first pipe segment, and the outer ring is clamped in the pipe joint between an end of the first pipe segment and an end of the second pipe segment.

9. The apparatus as claimed in claim **8**, wherein the second pipe segment is a first port of a multi-port pipe connector.

10. The apparatus as claimed in claim **9**, wherein the first pipe segment is a hub adapter for providing access to a well head of a subterranean well bore, and the first port is a top port of the multi-port pipe connector, and the multi-port pipe connector has a side port for inflow of fracturing fluid from a pump, and the multi-port pipe connector has a bottom port for outflow of the fracturing fluid to the well head.

11. The apparatus as claimed in claim **8**, further comprising the first annular seal clamped between an end of the first pipe segment and the first axial end of the outer ring, and the second annular seal clamped between the second axial end of the outer ring and an end of the second pipe segment.

12. The apparatus as claimed in claim **8**, wherein the first pipe segment has an internal diameter less than an internal diameter of the second pipe segment, and the axial vanes protrude radially inward from an inner circumference of the outer ring to the internal diameter of the first pipe segment.

13. The apparatus as claimed in claim **12**, wherein the first pipe segment has a tapered transition from the end of the first pipe segment to the internal diameter of the first pipe segment, and the axial vanes conform to the tapered transition and protrude axially into the tapered transition.

14. The apparatus as claimed in claim **12**, wherein the axial vanes protrude radially inward no further than the inner diameter of the first pipe segment.

15. A method of vortex suppression to mitigate erosion from particulate laden fluid flowing in a pipeline, the method comprising:

(a) locating, in the pipeline, a pipe joint at a location where a vortex would form in the particulate laden fluid flowing in the pipeline in the absence of a vortex suppression element in the pipe joint in the pipeline; and

(b) inserting a vortex suppression element in the located pipe joint in the pipeline, the vortex suppression element having an outer ring with a first axial end and a first circumferential lip on the first axial end and a second axial end and a second circumferential lip on the second axial end, an array of inner axial vanes secured to the outer ring, the inner axial vanes protruding axially from the outer ring, each axial vane including an inner surface extending axially and an outer surface extending at an acute angle with respect to the inner surface, and the vortex suppression element also having a first annular seal engaging the first axial end of the outer ring and held to the first axial end of the outer ring by the first circumferential lip, and a second annular seal engaging the second axial end of the outer ring and held to the second axial end of the outer ring by the second circumferential lip.

16. The method as claimed in claim **15**, wherein the particulate laden fluid is fracturing fluid, the pipeline conveys the fracturing fluid from a pump to a well head of a subterranean well bore, the located pipe joint is a joint between a well access hub adapter and a top port of a multi-port pipe connector, and the multi-port pipe connector also has a side port for inflow of the fracturing fluid from the pump, and the multi-port pipe connector also has a bottom port for outflow of the fracturing fluid to the well head.

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